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FEBRUARY, 1961
Vol. 44 • No. 5

The HIGH SCHOOL JOURNAL

The Challenges in Science Teaching

THE UNIVERSITY OF NORTH CAROLINA PRESS

The HIGH SCHOOL JOURNAL

SAMUEL M. HOLTON, *Editor*
Professor of Education, University of North Carolina

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Published Monthly, October through May, by the University of North Carolina Press for the School of Education of the University of North Carolina. *Subscription Price $3.00; clubs of five to nine, $2.50 each; clubs of ten or more, $2.25 each; single copies, 50c.*

Subscriptions and Advertising are handled through the University of North Carolina Press in Chapel Hill, North Carolina, to which communications pertaining to business details should be addressed. Entered as Second-Class Matter, March 1, 1918, at Post Office at Chapel Hill, N. C., under Act of March 3, 1879.

All other communications, articles submitted for publication, and books submitted for review should be sent to *Editor, High School Journal,* Box 810, Chapel Hill, North Carolina.

The HIGH SCHOOL JOURNAL

Vol. XLIV ✕ February, 1961 ✕ No. 5

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Issued Monthly, October to May, Inclusive $3.00 a Year

Published by the University of North Carolina Press for the School of Education of the University of North Carolina.

SAMUEL M. HOLTON, *Editor*

Editorial Office: Box 810, Chapel Hill, N. C.

Business Office: Box 510, Chapel Hill, N. C.

The Challenges in Science Teaching, K-12

JOHN B. CHASE, JR.
Associate Professor of Education
University of North Carolina

ON September 9-10, 1960, over three hundred high school science teachers, elementary school teachers interested in science teaching, school supervisors, and scientists met at The University of North Carolina, School of Education. This conference was the first regional conference of the National Science Teachers Association to be held in this area. This issue of the *High School Journal* is, therefore, devoted to the main addresses and reports of this conference.

It was the purpose of this conference to stimulate thinking about *The Challenges in Science Teaching*, K-12. Certainly in recent years there have been many factors which have challenged the best in science teaching. With the beginning of an exploration of space, the development and refinement of instruments and techniques for better scientific research, and the vast explosion of knowledge in all fields of learning it is wise that attention was brought to the quality of elementary and secondary school teaching. Because of the nature of the various developments, it is natural that the teaching of science should be brought into the forefront.

There has probably been no time in the development of science teaching in the elementary and secondary schools of America in which more emphasis, more study, and more money have been given to science teaching than today. Likewise, the teaching of science emcompasses more problems than ever before. Should there be a national curriculum in science? What should be the relationship between pure and applied science in the elementary and secondary school? How may articulation be achieved in the science curriculum? Should science be taught by the specialist in the elementary school? If not, how may the specialist best be used in the elementary school? What are the roles of the scientist and the layman in the development of the science curriculum?

These are but a few of the many problems of science teaching which merit the best of thought. The complexity of these and other problems, the interrelationships of the multiple factors which are within each problem, and the elements of time and personnel preclude quick, ready, and easy answers. National groups such as the Physical Science Study Commission, the curriculum and film committees of the American Institute of Biological Sciences, The

National Science Foundation, The National Science Teachers Association, and others have produced valuable materials and are studying individual problems. Local and state committees are at work. Universities, colleges, and scientific societies are at last assuming various roles of leadership. However, as valuable as the products and recommendations of these and other groups may be, is there not danger in accepting immediate results as a ready, easy answer?

Certainly, current materials and recent recommendations have been welcomed by the profession of classroom teachers of science. Should not these be accepted as tentative rather than the final answer to all problems for all times? In years to come, will present recommendations not be out of date? Surely, science education needs rethinking and the changing challenges in science teaching need continuous study. As the many challenges of today, and of those to come, are met, what happens to the scope and sequence of content? What will happen with the time in the laboratory? And of most importance, what will happen to the learner in this process?

ANNOUNCING

The Second South-Eastern Regional Conference of the National Science Teachers Association will be held September 8-9, 1961 at the School of Education of the University of North Carolina. The theme will be:

LEARNING SCIENCE AS AN INDIVIDUAL EXPERIENCE

For program announcements, registration information, and room information, write directly to:

John B. Chase, Jr.
School of Education
University of North Carolina
Chapel Hill, N. C.

Re-thinking Science Education*

J. DARRELL BARNARD, *Chairman*
Department of Science and Mathematics Education
New York University

I WOULD LIKE to tell you a story about a young lady. Her name is Henrietta. Henrietta had been brought up in an eastern public school. She had attended a good elementary school, one that had an unusually fine science program. Academcially the junior high school which she had attended was among the best in the country. The high school from which she had graduated had an outstanding record for preparing its students for college.

I met Henrietta after she had completed her freshman year in a mid-western university. To make conversation with this 18-year old, I asked how she had liked her first year in college. She talked most of the social life and how enjoyable it had been to be with young people from many parts of the country. In reply to a question about the courses she had taken, she informed me that her college courses had not been too different from those she had taken in high school. She had taken college zoology, primarily because it had a title that was different from any of the science courses she had taken in high school. However, she hastened to add that she had found it quite similar. It too had turned out to be a collection of "animal" facts to be learned for purposes of passing examinations. When I looked puzzled she explained that science did not deal with big ideas such as the social studies courses which she had found most stimulating. Next year she planned to take either botany or geology and that would be the end of her "awful science requirement."

Henrietta's story depressed me. In fact I am greatly distressed by the number of Henriettas (and Henrys too) whom I meet among students at our college, and among many of my adult associates, including teachers, supervisors, and principals. Too many of them have written science off as an uninteresting, extremely difficult subject, that can be understood only by a relatively small number of queer people called scientists. Many of them think of science only in terms of complicated technological developments, dramatized by awesome bombs, jets, rockets, missiles, satellites, and astronauts. Relatively few appreciate science as a nobel human endeavor, on a

* An address delivered at the Regional Conference of the National Science Teachers Associations, September 9-10, 1960, at the University of North Carolina in Chapel Hill.

par with the humanities, and calling for the exercise of such unique human atributes as intellect, creative imagination, and an abiding faith that ultimately the unknown can be explained. Few of them realize that the most distinguishing characteristic of science is change. Having become accustomed to time-honored ideas and patterns of behavior, they find it difficult to accept the changes brought about by the dynamics of science. As one scientist has put it, "human beings seem predisposed to hold to their first ideas."

In so far as science is concerned we cannot afford the luxury of living in the past; nor can we indulge ourselves solely in the comforts of the present. We must anticipate an uncertain but different future in which many of our comfortable ways of believing and behaving will no longer be defensible. This has happened in the past and it is happening now.

After the discovery of microorganisms and establishment of the relationship of certain of them to disease, vaccination could be explained as a technological application of this new found knowledge. But there were many who would not accept vaccination as a way of protecting themselves from the ravages of a dreaded disease. Even in this enlightened age there are people who claim that such practices violate God's will for man.

Who would say that man has sinned by applying his best efforts to the control of disease? Who would say that the population explosion is the price we must pay for the sinful acts of such great men as Pasteur, Kock and Fleming? To those who have come to accept advancements in disease control, these questions sound absurd; but there are others who aren't so sure.

Through the discovery of the complex ways in which living things are interdependent, through the discovery of the ways in which living things interact with environment, through these basic science discoveries, a technology of land management has been developed. According to the new technology, many of the old land-use practices are destroying the land. New ways of using it must be adopted if we are to survive. The facts are clear! However, conservation technicians report that resistance to the adoption of the new practices is not at all uncommon. "What was good enough for my father is good enough for me."

These illustrations should be sufficient to make the point that man has resisted changing his way of behaving in light of technonogical developments. No doubt you could add others, some probably from your own experience.

Not only has man found it difficult to change his ways of behaving to correspond with new ideas, but his ways of thinking as well. Historically, man has repeatedly found it difficult to adapt his way of thinking to certain major scientific discoveries. At one time he believed that the earth was flat. This was a common sense idea, one that corresponded with what he observed. But then came the change to an uncommon-sense idea, that the earth was a sphere. And now that we have learned to accommodate the idea of a spherical earth, we are told that the earth is pear-shaped.

At one time man believed that the earth was the center of the universe—another common sense idea. Furthermore, it was an idea that appealed to his ego—man at the center of all creation.

That the earth and all living things upon it were created as they are today, was an idea to which men once held. Now we are asked to accept the idea of a changing earth.

Many have found comfort in the belief that the earth is the only body in the universe that supports life. Now we are asked to accept the possibility that there may be millions of worlds like our own. It seems almost fictional to read that a group of reputable scientists are now attempting to determine whether there are radio signals coming from distant space that may have been broadcast by intelligent life on other worlds.

Our ideas have had to change from that of a static universe to one that is ever changing, from stars that are eternal to embryonic stars, mature stars, old stars and even dead stars.

That life comes from preexisting life seemed at one time to be an irrefutable fact, but now it would seem that under certain conditions life may be created in the laboratory. Today, spontaneous generation has been taken from the scrapheap of scientific misconceptions and accepted as a respectable problem for scientific investigation.

It is clearly evident that future scientific advancements will have a far-reaching affect upon people. We are told that the next big breakthroughs will probably be in the biological sciences. Since man is a biological organism, the new discoveries are getting closer and closer home. Today biologists are emphasizing the importance of the discovery of DNA and its primary role in the hereditary process. We may no longer use vague but comforting explanations of why we are as we are. In the future what we are may be explained in terms of what happened in a molecule of DNA.

As scientific discoveries are made the technologies follow rapidly. During the past twenty years we have witnessed how rapidly this

can happen in the field of atomic energy. It has been a relatively short time from the discovery of nuclear fission through the chain reaction to atomic bombs. In turn these bombs provided ways of building an energy-producing system comparable to that in the sun.

Because of such rapid developments as these some might hope for a moritorium on science. But to suspend scientific investigation is impossible. It is impossible because it contradicts man's God-given desire to understand—his impelling urge to know. Furthermore to suspend scientific investigation is impractical. It is impractical because of our growing dependence upon it for our survival.

The points that I have tried to make have significant implications for science education in these times. We need scientists. We need not just ordinary ones, but scientists who are brilliantly creative. Science education must play a major role in producing quality scientists. We need engineers. We need not just technicians, but engineers who are resourceful, adaptable, and above all creative. Here again science education has an important responsibility.

But most of all in this century we need a society that is scientifically literate. To produce a scientifically literate society is, in my judgment, the big task ahead for science education. To comprehend the nature of scientific literacy is to comprehend the magnitude of the task.

A scientifically literate society is one in which the masses of people understand the nature of the scientific enterprise. They understand that science is a process of human inquiry based upon an innate curiosity, a propelling desire to find out. They understand that science is an expression of a faith that the unknown can ultimately be explained in an orderly and reasonble manner. They understand that the knowledge which science yields is based upon the authority of demonstrable, reproduceable proof. A scientific literate society understands that science is a process of discovery; that it is dynamic and ever changing. However, the ideas which it yields are subject to change because science is a self-correcting process. They understand that technological developments, however awesome they may appear to be, can be explained. They can be explained satisfactorily, providing one is willing to become informed about the science involved.

Finally, the scientifically literate persons realize that scientists are not special creations, endowed with special insight. They

realize that the achievements of scientists have been won through hard work—yes very hard work—dedication and a faith that through persistence the informed investigator may come to understand better.

But this is not all. A scientifically literate society is one in which the masses behave in rational ways by seeking to comprehend natural phenomena based upon scientific interpretations. To do this they ask questions. They persistently search for evidence. They maintain open minds, but critical ones. They suspend judgment where the evidence is not convincing. They evaluate evidence and interpret it in order to arrive at decisions. And finally, they act with confidence in accordance with the best available evidence.

Today our major task in science education is to develop programs that will produce a scientifically literate society. To do this we must accept science as an imperative in the culture. This means that science must be taught at every grade level. It must be developmental from kindergarten to the twelfth grade. It should deal with all of the sciences, including the behavioral sciences. Most important of all it should be taught within the spirit of the scientific enterprise. Finally, it should reinforce learnings which are common to other curriculum areas. It should reinforce the language arts because the very foundation of scientific advancement is communication. It should contribute to the social studies for the ways in which science will relate to the lives of men have profound social implications. Its relationship to mathematics is obvious since mathematics is the hand maiden of science.

Merely to clarify the purpose of our task by no means accomplishes it. There are innumerable problems and much hard work ahead. Conferences such as this one, sponsored by the National Science Teachers Association in cooperation with local committees are indeed welcomed by those of us who are concerned in getting along with the task ahead. It is through participation in the deliberations of a conference like this one, that we gain additional insight into the ways that we as individual teachers, and the schools which we represent, can move ahead. It is here that we have the opportunity to rethink the many questions and issues in science education today. However, the process of rethinking science education has validity only to the extent that it results in action which carries us a little farther toward the accomplishment of our goal. And our goal should be to make science more vital for all of the Henriettas and Henrys in all of the schools throughout our great land.

Current Trends in Science Teaching

HELEN E. HALE
Supervisor, High School Science
Baltimore County, Maryland

THE CURRENT interest of the public in education has given impetus to the normal development of ideas in all phases of the school curriculum. A particularly marked effect can be noted in the science program. Trends which have been developing a long time are now accelerating. Some old ideas have been refurbished. Some unique ideas are being born!

Perhaps a dozen of these trends are worthy of mention. They will, of course, overlap and interrelate; but, set down separately, they can become a check list for use in surveying your own science program. This does not imply that all of the developments are equally salutary. In general, however, they seem to represent improvements in the science-teaching situation in elementary and secondary schools.

1. *The Trend Toward an Articulated or K-12 Science Sequence*

An important trend concerns an articulated program of science instruction. For thirty years, the educators have been writing about the need for a sequential science program to run for the kindergarten through the twelfth, or in some cases, the fourteenth grade. At last, we have some developments. A few places, among them Atlanta, Georgia, have worked out a scope and sequence of science concepts for grade K-12.

What does this kind of arrangement mean? In the elementary school, it means that science is in a less subordinate position than it once occupied. Elementary science is no longer nature study or merely incidental science or a few science concepts attached to a social studies program. It may still be a part of the social living program, but if it is, many of the social living units are now science-centered enterprises. A science sequence means, of course, that there is time in the daily and weekly schedule for science. It means, perhaps, that there is less choice of operation for the pupil and teacher, at least as far as the general areas to be studied are concerned. However, it does not mean that science is unrelated to the total learning situation in the elementary classroom. To quote from a recent publication of the NEA,—"Science instruction integrates with other curriculum areas when such relationship is important, and it proceeds on its own when its contributions are best

realized by doing so."—(p. 18 *It's Time for Better Elementary School Science.*)

What does a K-12 sequence mean at the junior high school level? The trend is for it to mean that science is part of general education, and that all students study it for the three years of the junior high school. As I shall mention a little later when I touch upon some provisions for able students, it does not mean that all pupils have to study the same science or at the same rate, but only that there are sequences of learning set up for each group of students. As a matter of fact, dual sequences may obtain at the elemenetary school level.

In the senior high school, you may have as many as three or more science sequences according to the number of different kinds of programs you are able and willing to set up. O course, there will be considerable overlapping of concepts, even when substantially different programs are devised.

At all levels, a sequential program means that there is some prescription. Units and even learning problems and suggested activities may be worked out for each grade level. However, in most school systems which are developing science sequences there is ample provision for teacher and pupil creativity in modifying the the program in terms of the needs, interests, and abilities of a particular class.

A sequential program is an articulated program. When teachers at all grade levels work together to develop a science curriculum, needless repetition is eliminated in two ways: (1) through actual curriculum bulletins, and (2) because teachers have the opportunity to understand thoroughly the science work which precedes and follows that which they are teaching.

A sequential program is also a balanced and interrelated program. There are several kinds of balance in a good science curriculum: between classical concepts and current developments, between principles and applications, between science as it relates to the local scene and science at the international level, and among the various branches of biological, physical, and earth science. Interrelationships among the sciences including mathematics and between the natural and social sciences should also be emphasized.

2. *The Emphasis on Science as an Intellectual Pursuit*

A second development in present-day science programs is the increased emphasis on science as an intellectual pursuit. Rabi has accused the schools of teaching science as a "body of tricks" and the Physical Science Study Committee has said that the schools teach

physics as "gadgetry or technology." We accuse ourselves of having failed to develop among our students an understanding of the nature of science and of the history of the development of ideas:—i.e., of the way in which men and women have "created ideas to solve those problems which are suggested by the relationships among events and circumstances in the natural envirnoment." We have failed to teach science as an intellectual, creative activity of the human mind. There is a tendency to correct these failures.

In many new curriculum guides and textbooks, there is an emphasis on the way in which individual scientists, both historical and contemporary, have established facts and created theories—the thinking they have done, the experiments they have carried out. This case-study approach, popularized by Conant at the university level and adapted to the secondary school by Leo Klopfer, appears to be gaining favor. The hope is that students will come to understand what is meant by science as they repeat both the thinking and doing of particular scientists. The growing popularity of individual experimental projects is another manifestation of this same emphasis.

Most new curriculum materials, even at the elementary and junior high school levels, play down applications and emphasize concepts, principles, and understandings. As we go higher up the educational ladder there is an increasing level of sophistication of conceptual material. Further, opportunities are given students to explore particular areas in depth. Applications are included to clarify concepts and to explain the results of the scientific enterprise. However, there are fewer units on "The Science of the Home," "Community Science," and the like, and more on "The Structure of Matter," "Forces in Air and Liquids," and other purely scientific topics. The applications are still there but they are fitted into the framework of *science* units.

There is also increased attention in the curriculum to the nature of science itself. Teachers set out consciously to debunk the "sacred cow" myth about science. They help students to see that scientists are ordinary human beings who use many methods in their work. They point out the limitations as well as the possibilities of science. The tentative nature of scientific conclusions is being stressed; the rule of conceptual models is introduced; and the self-correcting nature of science is emphasized. Scientific inductions are presented as probabilities and students are taught to tolerate uncertainty. Science teachers and textbooks and curriculum guides are learning to avoid the word "prove" and to substitute the

phrases, "This seems to show," "It is probable that," and "At present it appears."

All in all, it seems that elementary and high school science are growing up. Science is taking its place in the curriculum as one of the humanities. This increased emphasis on the intellectualism of science appears to be in line with the recommendation of Conant and of other educators and scientists of national stature.

3. *The Growing Importance of Quantification at All Levels of the Science Program*

A third trend has to do with an increasing attention to the quantitative aspects of science. Even in kindergarten children learn to accumulate numerical data and to base conclusions on this data. They learn to talk about scientific notions in quantitative terms. In later grades students become adept at expressing the laws of science graphically and mathematically, and at the secondary level they learn to handle dimensional analysis and to derive scientific laws through mathematical procedures. One superficial manifestation of this trend toward increased mathematics in the science program is the use of slide rules by most chemistry and physics students and by many junior high school pupils as well.

4. *Efforts to Promote Genuine Experimental Activities*

A fourth trend concerns an emphasis on the process of science, an effort to provide a genuine science experience for boys and girls. The science experiences for elementary school children capitalize on their curiosity and are designed to promote the spirit of inquiry. Boys and girls learn to set up simple problem situations. They are led to discover instead of being told the principles of science. In the secondary school the "Tactics and Strategy" of the scientist are further exploited. As noted earlier, students learn how both historical and contemporary scientists have gone about the business of being scientists and then are encouraged to engage in modes of thinking and behaving used by scientists: discriminatory observation, categorization, quantification, hypothetical explanation, analysis and synthesis, correlational thinking, and construction of broad theories or scientific models. Special laboratory programs have been designed which, to a degree, require the above-mentioned modes of thinking. In a new biology program, for example, each student works with a living organism over a period of two or three months, learning first to keep it alive and then to design an experiment which varies one factor in the organism's environment. The student keeps accurate records during the several months he is working with the organism. This type of sustained, experimental

experience gives him more opportunity to act like a scientist than the typical one-period, follow-the-direction-sheet laboratory exercises. Similar, non-recipe laboratory programs have been worked out for chemistry. The PSSC laboratory program for physics exhibits a similar quality of discovery.

5. *Provision of Better Teaching Materials and Facilities*

A fifth trend has to do with teaching materials and facilities for science. In general, more and better materials are on the market, and more and better materials are being provided in the schools. Consider books, for example. A great deal of time, money, and ability are being invested in new elementary science textbook series. And the products are excellent: handsome books, carefully controlled vocabularies, and honest attention to the problem-solving goals of science teaching. The trade books written on science topics for the children's market are rolling off the presses faster than the reviewers can keep up with them. Science books at the high school level are being provided for pupils with low reading abilities, and, at the other end, for particularly able students. The use of college-level texts and references by high school classes is increasing. Pamphlet material on recent developments in science and other science topics is being provided by the publisher and by professional societies, industrial groups, and other organizations. These same sources are offering charts, films, filmstrips, and other visual materials to aid the teacher.

Laboratory facilities are being extended. The trends: a self-contained classroom-laboratory for each secondary school science teacher, some special provisions such as science tables in the elementary schools, well-stocked supply rooms and adequate storage, well-designed preparation rooms equipped with utilities, special project centers or laboratories for the gifted student, school science shops where students may develop their own equipment, and auxiliary provisions such as planetaria, weather stations, greenhouses, nature trails, and other outdoor science classrooms.

As far as materials and supplies are concerned trends include: (a) increased allotments, (b) increased variety of provisions to accommodate recent scientific developments and emphases—I am thinking of such things as geiger counters, binocular microscopes for work with fruit flies, colchicine, radioactive isotopes, and oscilloscopes,—and (c) the most interesting trend of all, some tendency to break away from tradition and the domination of the colleges in order to provide developmental materials and supplies from which the students can devise their own equipment, or to provide

unique experimental aids, usually simpler and better adapted to elementary and high school use than much of the equipment and material found in the science catalogs. The laboratory materials supplied for PSSC physics are indicative of this trend. Interesting, accurate, and meaningful experiments have been devised using soda straws, blocks of wood, and simple supplies from hardware and ten-cent stores.

In view of the trend toward the use of homely materials and do-it-yourself science equipment, there is considerable pressure to set up petty cash funds for science teachers. A publication prepared and circulated by an impressive array of organizations—the AAAS, AASA, CCSSO, NASSP, and the Scientific Manpower Commission in cooperation with the U. S. Office of Education recommends that each regular school budget should include a petty cash allotment of $50 per science teacher.

6. *Attention to the Special Needs of the Able and Highly Activated Science Student*

A sixth development relates to programs for pupils of unusual ability and interest in science. The provisions are largely curricular with acceleration and enrichment of content, science seminars, and club programs for the elementary school; content acceleration, and some special courses at the junior high school level; and honors courses, advanced placement courses, and some brand new courses and special activities in the senior high school. Incentive programs, including science fairs—and other forms of recognition and awards, are proliferating at all three levels.

I might mention one of the special courses. In Montgomery County, Maryland, teachers have developed a Brandwein-type science course for able ninth-graders. Goldstein's *How To Do An Experiment* is the basic text; and after the students have learned the genesis and the techniques of scientific experimentation (including, incidentally, library research), they work individually on projects of their own devising. This is an entire course devoted to the "Tactics and Strategy of the Scientist." In a great many places biology is being given to superior and gifted pupils in the ninth grade, and chemistry and physics moved down to the tenth and eleventh grade. This allows scheduling room for advanced placement or other special courses in the senior year.

The so-called honors courses for able students are in keeping with a trend that we need to "toughen" the high school program. Honors courses vary from system to system, but their main features are that the work is presented on a more conceptual level than in

the regular science program and that considerably more in the way of thinking and doing is required of the students.

Summer opportunities for able and highly motivated science students are increasing. For four summers, the physics laboratories at the University of Maryland and a number of different laboratories at the Bureau of Standards in Washington have employed outstanding high school students. The U. S. Office report to which I referred earlier recommends that all schools should use interested students as preparation assistants in the school science laboratories. Many schools are already doing this. Summer science camps and seminars are springing up all over the country.

Some attention, but not nearly enough, is being given to low ability and poorly motivated students in science. Many schools have set up courses on different levels and others are providing special courses for low-ability students. In one system, for example, a new biology course of study was developed on three levels. The program for poorly motivated and low-ability students stresses study of the human body and gives attention to local plant and animal populations of the Chesapeake Bay rather than more remote ecological considerations; it avoids the physio-chemical aspects of living things, and the abstract theoretical considerations of modern genetics, population fluctuation, homeostasis, and the like. More of this kind of attention is needed. Since we are living in an age where science is playing a more important role every day, we have particular responsibility to these boys and girls. They comprise one-half of our total population and need to understand the place of science in our society. As soon as the concern for the "gifted" dies down a bit, I predict that we will give more thoughtful attention to the "science shy" as Fletcher Watson has termed these students. I sincerely hope that this prediction comes true.

7. *Wide Use of Resources Personnel*

Some of the urban areas of the country have, for many years, been utilizing the human resources in their communities to improve and enrich the science program in the schools. In other areas, this is a fairly new trend. Many communities are, for the first time, using trained personnel from the colleges, universities, industry, and the professional societies in three main ways: (1) in curriculum development activities; (2) in seminar programs and actual teaching situations, and (3) in auxiliary capacities such as science fair judges. It is likely that the local public interest in the science programs of the schools will continue and that greater

use of scientists in the actual preparation of curriculum bulletins will benefit the schools immeasurably.

8. *Interest of the Federal Government in Science Teaching*

An eighth development is the increasing importance of the federal government in the science picture. Traditionally, the role of education in our nation has been considered to be a function of the state. Through the decades, however, the federal government has shown certain responsibility and activity, particularly in some aspects of vocational education. In recent years the federal government has attempted through many departments and agencies to give aid to the teaching of science. With the appointment in 1956 of a National Committee for the Development of Scientists and Engineers followed by the President's directive that "all departments and agencies of the government are to cooperate fully with the work of the National Committee and, at the same time, to re-evaluate and strengthen in every appropriate way their own activities which can contribute to the development and effective utilization of scientists and engineers," activity was stepped up. In general, federal agencies have provided four kinds of aid: (a) opportunities for teachers and students to observe current research in laboratories directly operated by the agencies, (b) participation by students and teachers in government research programs, (c) attendance at National Science Foundation sponsored summer and academic year institutes, and (d) programs for the preparation of newer, more effective curriculum materials and laboratory exercises. The most recent federal move to strengthen science teaching has been, of course, the National Defense Education Act of 1958. Under Title III of the bill—*Financial Assistance for Strengthening Science, Mathematics, and Modern Foreign Language Instruction*—state educational agencies are receiving federal aid for projects of local educational units which provide facilities and equipment for the three subjects named in the title. However, states or local school systems must match federal funds on a one-to-one basis. Non-profit, private schools may secure loans for similar projects. A third provision makes possible federal grants to state educational agencies for expanded supervisory services in the sciences, mathematics, and modern foreign languages as well as for minor remodeling of laboratories. After the first year (1959) these funds, too, had to be matched by the states. An appropriation of $300 million was made to carry out Title III of the bill during the four fiscal years, 1959-1962.

9. *Proliferation of Services by Other Auxiliary Agencies*

In addition to the agencies of the federal government, many other organizations and groups have offered their services to help improve the secondary school science program. It would take a great deal of space to describe the varied efforts of business-industry groups, the professional societies, and the philanthropic foundations. To summarize briefly, these organizations have done the following things:

a. *Business-industry groups* have prepared booklets, charts, films, and other aids; organized tours; sponsored incentive programs for students, institutes for teachers, and science camps; hired teachers and students for summer work; farmed out research projects to teachers and students; distributed surplus equipment; provided speakers and substitute teachers for the classroom and consultants for students working on projects; and awarded scholarships.

b. *The professional societies* have published journals; held meetings, institutes, and conventions; prepared special publications; provided consultant services; promoted research; developed tests and other teaching materials; provided science counselors and visiting lecturers; and recognized teachers and students through awards programs.

c. *The philanthropic foundations* have made substantial grants to support programs aimed at the improvement of science teaching. The PSSC program has received $950,000 from three private foundations. The FAE has granted the University of Florida a half million dollars to film a high school chemistry course. Harvard has received a $100,000 grant from the Alfred P. Sloan Foundation to establish fellowships for secondary school science teachers. The Shell Companies Foundation has a broad program including 25 four-year scholarships for high school seniors who plan to teach high school science or mathematics as well as summer programs for teachers at Cornell and Stanford. The Esso Foundation is sponsoring a number of programs for high school teachers of both science and mathematics. Many, many similar efforts might be named.

The colleges and universities are also giving aid to science teachers in the schools, and even individual citizens sometimes feel called upon to offer their services. All in all, the present and projected efforts of various groups to supplement the work of the local and state school systems in improving science instruction represent a considerable force.

10. *The Science Teacher as Career Counselor*

A tenth development is the evolving role of the science teacher as a career counselor. Because of the nation's need for scientists, engineers, technicians—and science and mathematics teachers—there has been considerable pressure to publicize this need through the schools. Government, industry, business, and the professional societies are making available to teachers a wealth of promotional material including booklets, films, posters, and filmstrips. These materials indicate the nation's need for increased technical manpower and give information about the scope and opportunities of various occupations. Formerly, this kind of material was directed to the guidance office, but there is now a trend to circularize the science teachers as well as the counselors. Actually, the science teacher is in a key position to give information about careers at a time when the students want and need it most; and it now seems that many science teachers feel an obligation to reenforce the work of the counselor in informing the students about careers in science and science-related fields. However, most science teachers also feel an obligation to maintain a balanced point of view about the role of science in today's world and to guard against overremphasis on scientific careers. In the best situations, career counseling is included as an integral part of the total science program, but the main concern of the science teacher is teaching science well. However, a generally effective science teacher will probably be the best possible stimulus for getting students to consider scientific and technical careers.

I might mention one word about "Science's Unclaimed Treasures," as women were described at the 1958 AAAS meeting in Washington. It does seem that teachers might well point out to the girls in their classes that scientific careers are not "strictly for the boys."

11. *Extension of the Science Program Beyond the School Day and Year*

The eleventh trend in present-day science programs is an extension of science beyond the school day and year. The Joe Berg Foundation, various academies of science, other outside groups, and many schools themselves are sponsoring seminar groups for students with particular interest and talent in science. These usually meet in the evening or on Saturdays. Many school systems have established summer science programs and science camps. Both community and school facilities and personnel are employed in these extended science activities.

12. *Changing Status and More Effective Utilization of the Science Teacher*

A final trend concerns the science teacher himself. All of the other developments—the *K-12* articulated science sequence, the intellectualization and quantification of the science program, the efforts to promote genuine investigative science experiences, the provision of improved teaching materials and facilities, the special programs for the science-gifted and the science-shy, the wide use of resource personnel, the interest of the federal government in science teaching, the contributions of auxiliary agencies, the inclusion of career information in the science curriculum, and the extension of the program beyond the school day and year—have led to an important but fairly recent change in the attitude of the general public toward the science teacher. Today, no one has to tell a science teacher that he is important. He hears it on television, reads about it in the papers, and senses it when he is recognized in the community as a science teacher. All of this attention is pleasant, but it brings with it increased responsibilities. More is expected of science teachers today than ever before—and here, I include elementary teachers as well. The general public and all of those interested agencies are looking to the schools to do a superlative job of teaching science. This means that each teacher must keep informed about recent developments in science—not a mean job in itself—must delve deeper into the history and philosophy of science, must take time to find out what is going on above his own grade level, must learn how to use effectively all of that new equipment, must figure out new courses and other ways to challenge those able students, must do a similar job for the less able student, must get out into the community to work with those people who are eager to help him, must keep abreast of the services offered by the government and other agencies, and must find time to participate in the numerous in-service activities which are being organized. In many ways the science teacher's job is an impossible task. It is for this reason that a few school systems are experimenting with teaching teams while others are employing laboratory assistants and clerical aids to ease the science teacher's burden. But despite the enormous responsibility which the science teacher has, despite the staggering proportions of his job, he is in a better position today than he has ever been before. He is respected, and honored, and supported. It's an exciting time to be teaching science!

Future Scientists of America

WILLIAM P. LADSON, Director
Future Scientists of America
National Science Teachers Association

THE INTENSIVE search for Future Scientists of America is being aided by the establishment of a new youth organization bearing the same title. Newest of the many services rendered by the National Science Teachers Association to the science teachers of the United States, the FSA will embrace as its initial offerings the following facets:

1. The chartering of school science clubs as chapters of the FSA.
2. An *FSA Sponsor's Guidebook* for teachers containing suggestions for operation of an FSA chapter and appropriate related activities that confront the science teacher during the year.
3. The production of a quarterly newsletter published by FSA containing news and a description of the work that is taking place in the existing FSA chapters.
4. A charter plaque for the school and personal membership cards for students will be presented. Pins and other insignia will be available at a modest cost for those members who desire them.
5. A "Vistas of Science" series of paperbound books, each consisting of a historical view, an approach to research, and a project section for students within a particular science discipline.
6. Suggestions for the operation of a science youth congress in which students meet and present papers about work they have accomplished during the year.

The inauguration of the FSA occurred during the week of October 15-22, 1960, which was within the confines of National Science Youth Month. The FSA has been four years in its development and is the only science youth organization requested, designed, administered, and improved by science teachers, and dedicated to the locating, nurturing, and directing of science-prone students into science careers.

For further information about F.S.A. write directly to Mr. William P. Ladson, Director, Future Scientists of America, National Science Teachers Association, 1201 Sixteenth Street, N.W., Washington 6, D. C.

The Challenge of Science Teaching in the Junior High Schools

ROBERT C. HANES*
Winston-Salem (N. C.) Public Schools

THE MODERN junior high school is built upon an ever increasing understanding of the nature of adolescence and the develmental needs which this growth period creates. A school curriculum which is based upon this knowledge of adolescence will reflect certain basic assumptions. The first of these is that there are learning experiences which every twelve, thirteen, and fourteen year old student needs. These learning experiences include the development of competencies in oral and written communication, the building of worthwhile concepts concerning the society in which one must live, the developmnet of an understanding of the physical aspects of our world with their social implications, and the development of a realistic and satisfactory self-understanding.

A second basic assumption is that each junior high school student needs training and experience in using the problem-solving approach. This is important not only because subject fields lend themselves to this technique but also because the young person of today experiences a multitude of problem situations in his daily activities. The degree of success and happiness which he achieves will be directly dependent upon the skill he employs in identifying and analyzing these problems, in reaching adequate conclusions based upon the available evidence, and in being able to act intelligently on the basis of the conclusions reached.

A third assumption is that each junior high school student should have the opportunity to explore many different fields of interest. It is through this kind of exploration that the student's intellectual horizons are extended to the point that wise selections of fields of study may be made in his later schooling. A fourth assumption is that the junior high school years should be a time of developing interest in possible career fields. This phase of the curriculum is closely related to the exploratory aspects of the curriculum and implies a considerable emphasis upon pupil guidance. A curriculum, therefore, which is designed to achieve these ends should include (1) broad general courses, (2) specialized

* Dr. Hanes is Director of Secondary Education for the Winston-Salem, North Carolina City Schools. An interesting program of "Common Learning" is underway in the Junior High Schools of Winston-Salem, N. C.

courses, and (3) exploratory courses.

Modern science has increasingly come to be accepted as a body of general knowledge about which every citizen must have some understanding. This statement has three implications for science teaching. The first of these is that scientific developments must be understood within the context of a modern society. The second implication is that science instruction at the junior high school level must provide an orderly, carefully laid out course in which students discover through experimentation scientific truths that are new to them. The third implication is that junior high school students need opportunities to explore the sciences with a view toward their possibilities as future career fields.

The first of these implications may be achieved through a core class. A core class is a broad general course referred to earlier as one type of course found in the modern junior high school curriculum. It is one which involves an extended period of the school day, usually two or three hours. It is a course in which two or more subject matter fields are combined in such a way that the traditional subject matter barriers are lost. Involved in the class organization is an extensive reliance upon pupil-teacher planning. This planning is used to organize the course around broad topics or problems of contemporary interest. A problem-solving approach is used which allows for all media and sources of information to be brought to bear upon the solution of the problem at hand.

To illustrate, a problem area of study often found in a core class deals with human and natural resources. Through pupil-teacher planning, the class may agree to approach the topic more specifically by raising the question "Why Is Food A Significant Natural Resource?" The class would then conduct a preliminary investigation of the topic in order to determine the materials available which could be used in the study and what information the class already knew about the topic. As a result of this preliminary investigation, the class would identify several sub-topics which need to be studied. Some of these sub-topics could include the following: How May Food Supplies Be Increased, What Problems Are Involved in Soil Development and Specialized Farming, and The Effect Food Supply Has Upon Man's Culture. The class would be divided into committees to investigate each of these topics. These committees would draw upon the classroom library, school and community libraries, the science teachers, and local agricultural experts to gather the information needed. Thus, each committee would analyze the data and reach conclusions relating to its phase of the

problem area. Through reports to the class, each group would share its work with the other class members. Class discussions and analyses of the committee reports would serve as a basis for the conclusions reached by the entire class.

If the core class were studying energy as a natural resource, the class would need to begin by raising such questions as: What Is Energy; Why Do We Need Energy; What Are Some New Sources of Energy; How Can These Sources of Energy Be Used Wisely; What Will These Sources of Energy Cost Us in Labor, Money, and Brain-power; What Will These New Sources of Energy Contribute to Our Society; and How Can Citizens Accept and Understand the Value of New Sources of Energy. The approach in finding answers to these questions would be similar to the approach used in the study of foods. Thus, the core class learns (1) much factual information about scientific topics, (2) why scientific developments must be faced and used by society, and (3) how to apply an inquiring approach similar to that found in a laboratory.

The second implication for science in the junior high school deals with the teaching of science as a specialized course. Such a course would meet for at least one hour a day, be taught by a certified science teacher, and have adequate facilities for individual and small group laboratory activity. It may be general science, physical science, earth science, or biology.

The fundamental objective of these science courses is to develop within students an understanding of science and the ways of the scientist. Because of the implications of science to our modern society, this understanding must become a part of every student's experience. This is not to say that every student should develop a desire to continue a study of science and become a scientist. It does mean, however, that every student should acquire scientific understanding in order to become an informed citizen. To develop maximum understanding and appreciation of science, students must acquire the ability to analyze, to associate, to reason.

A specialized science course, to achieve these objectives, may be organized around scientific concepts basic to that particular subject and appropriate to the background of the student. "Energy, potential or kinetic, exists in all matter and brings about all changes on the earth and in the universe" is an example of a concept appropriate for a junior high course in physical science. Units would be organized and activities selected which best lead students to an understanding of this as well as other concepts.

While many varied methods are used in the teaching of a specialized science course, laboratory activity is perhaps the most important. Laboratory experimentation is the essence of science and its value in stimulating interest, and thus providing motivation, cannot be over estimated. Since it does provide motivation, students are able to develop true understanding because they become totally involved in the situation. Even more important, through actual experimentation the student learns to use elements of scientific thought and to use and appreciate the ways of the scientist.

The laboratory program in specialized courses would involve many different types of activity. Manipulation, verification, experimentation, and reading are all essential, yet the ultimate objective is true experimentation. "How can plants be grown with chemicals" and "What elements are present in leaves from the oak tree" are examples of problems which will involve experimentation. Prior to undertaking the solution of either of these problems, however, the student would participate in activities to learn to verify the existence of chemical elements and to manipulate the necessary apparatus.

The third implication for science in the junior high school involves the exploratory aspect. The primary objective is to help students become familiar with possible careers in science. Two approaches may be used at this level. One is through the exploratory science course. This course would be designed to allow the student many opportunities to become familiar with the world of science. Laboratory activity would be the dominant teaching method and student interest a primary guide in determining course content. Such a course would meet at least one hour every other day. It would require a small enrollment and individualized instruction would need to be stressed. Laboratory units would be derived from all areas of science and the course syllabus would consist of suggested laboratory activities.

The second approach in the career area is through the specialized courses. The very nature of these courses provides many opportunities for students to explore and to form impressions concerning possible career opportunities in science. In addition, the teachers of these courses may continually provide opportunities for students to explore career fields through contact with local scientists and through reading.

"Challenges in the Physical Sciences"

SHERWOOD G. GITHENS, JR.
Deputy Chief Scientists, U. S. Army Research Office (Durham, N. C.)

THE GREATEST ultimate challenge in the physical sciences, in my opinion, has to do with maintenance of the world's supply of energy. We are not short of energy today, as evidenced by the abandon with which we throw away energy, for example by running around in millions of individual units, automobiles, instead of using mass transportation units, and by flying when in many cases we could get there just as well by land or water, and so forth. But this "age of plenty" may not last forever. It is possible that our grandchildren may look back upon this present generation as a group of irresponsible and improvident wastrels.

The world's supply of coal and fossil fuel will last for another two to five hundred years, and the materials for nuclear-fission energy probably will last for a thousand years, and so our own generation has little to worry about in this respect. But our children's children may find themselves in a jam if the world's population continues to grow at its present explosive rate, and if we continue to raise the standard of living all over the world, each year seeing a further increase in the per-capita and total consumption of the world's energy. By 1970 the U. S. population alone should reach 200 to 225 millions.

Energy is a basic ingredient in civilization. A principal reason why this nation has been able to advance more rapidly than others in the past 150 years is that our forefathers had the good luck and the good judgment to move into a large chunk of land blessed with energy stored in vast stands of timber, in edible animals, in untilled soil, and in coal and oil, plus huge stores of other things such as iron ore, all untapped by earlier generations, accumulated and unused, free for the taking, and not restricted from general use either by a fascist-type government or by selfish or unprogressive land barons. The day of exhaustion of some of these stored resources is nearly here. We do have a big stockpile of fission-type nuclear fuel, but this supply is not without limit. Also it costs a lot to tap this supply of energy, and there are problems in the disposal of the waste products.

The problem of what to do about the world's exploding population falls in the field of government and political science, and with

some sense of relief I shall leave birth control to be wrestled with by the eleven o'clock speaker! The physical scientists may be called upon to build platforms out over the oceans, to provide additional living space! This is not impossible, provided we have enough energy to prepare the materials and do the job of construction. And it may be that the physicist, rather than the agronomist, will hold the key to an abundant food supply, a supply that is adequate no matter how big the world's population becomes. It has been said that enough food could be grown on the arid land in the southwest part of the United States to feed all the world, provided this land were adequately irrigated. It is quite possible to de-salt ocean water and to pump it to these land areas—all it would take is energy, cheap energy in great amounts.

The leading thinkers and planners of the world are not unmindful of the keystone importance of energy. Much effort, time, and money have already been spent in recent years in physical-science research with energy as the goal. The principal areas of this research have been in nuclear fusion energy and in solar energy. To a lesser degree, exploration has been made in the possibilities of energy supplied through wind power, action of the ocean waves, ocean tides, thermal springs, and natural steam wells. None of these energy sources has been found, as yet, to be at the same time feasible and adequate.

Energy is derived through nuclear fission, from the disappearance of mass when atoms at the heavy end of the nuclear species split up. The principal drawbacks connected with this energy source are that control of the process and capture of the released energy are not simple; the supply of heavy atoms is not limitless; and the end products are radioactive.

Energy may also be derived through nuclear fusion, from the disappearance of mass when atoms at the light end of the nuclear species combine. In this case the supply of fuel atoms is limitless, and nonradioactive end-products are possible; but the catch is, we have not yet learned how to control such a reaction. We can generate such a reaction; but the thermonuclear bomb goes off with a big "bang," and nobody benefits from the tremendous amount of energy thus released.

The "fuel" required for a nuclear fusion energy source is deuterium. Theoretically, a pound of deuterium should yield 10 million kilowatt hours of energy. It is estimated that a cubic mile of sea water contains enough deuterium to supply the power requirements of the U. S. at its present rate of consumption of 10,000 years.

Incidentally, the energy that falls upon us from the sun constantly is derived from a thermonuclear reaction that has been going on for about 3 billion years and is expected to continue without much letup for another 8 billion years! When we derive energy from wood or grass or coal or oil, we are tapping radiant energy which arrived here from the sun perhaps millions of yeaes ago, and which was captured through vegetational growth. It has been estimated that the sun bestows upon us daily more than ten thousand times as much energy as the world's daily requirement. Man has built in recent years a number of concave mirrors many feet in diameter, called solar furnaces, which focus enough energy into one spot to melt steel. A great deal of thought and effort has been given to these and other ways and means of capturing and using a greater part of the energy from the sun, much of which is now reflected away from the earth or is accepted in a fashion that renders it unavailable for immediate human use. However, except in a limited number of special instances, solar energy has not been harnessed profitably, and there is little prospect at present that it ever will be. A solar cell in an earth satellite *can* accept enough radiant energy to power a radio transmitter, but it is located above the earth's atmosphere. The latter sops up so much of the sun's radiation before it reaches the earth's surface that we would have to cover vast land areas with solar cells much more efficient than any achieved to date, in order to obtain solar energy in practical quantities.

If we could force the nuclei of light atoms into close-enough proximity to result in nuclear fusion, without using an atom bomb to do this trick, this should give the world its desired limitless supply of energy. The code name "Sherwood" was coined for the controlled thermonuclear power project which the AEC embarked upon in earnest in 1952. Incidentally, the head of Project Sherwood was and is a person known to many of you, Dr. Arthur E. Ruark, who was Chairman in Physics at Chapel Hill for a number of years. The AEC has taken this project very seriously. Through FY60, a sum of the order of $100 million was spent on it, and the present rate of effort is about $25 million per year. Thus, the U. S. is still working on it and so are several other nations.

If we could obtain boundless energy, this would be the key to the general comfort and happiness and ultimate world peace, provided, of course, that the political scientists and world leaders succeed in spreading the benefits equitably throughout the world and prevent any one nation from being selfish.

I do not consider a tenth of a billion dollars spent on Project Sherwood to have been unwarranted or a waste. We spent about twenty times this amount to develop the nuclear fission bomb, something with which to kill people; and 1/20 of that sum spent for something that could solve the major problem of the world for all time is peanuts.

Also, many by-product benefits have come from this thermonuclear research. It has helped the graduate training in physics for hundreds of people. Our knowledge of magnetic fields and their effects on materials has been vastly increased through the various attacks that have been made, however unsuccessful, on the problems of giving deuterium and tritium atoms sufficient energy to interact, and of containing the reaction elements and products. (All known substances vaporize at the temperature to which the deuterium and tritium must be raised, so these must be kept away from the container walls, and this is attempted by means of magnetic fields.)

With a goal so terrific in its implications, it is well worth while to gamble as much as $25 million per year for many years in the hope that some day, someone will hit upon the necessary bright idea which will permit having a controlled thermonuclear reaction in which the output energy is greater than that expended in obtaining and maintaining the reaction.

We have seen the emergence of several interdisciplinary topics among the physical sciences in recent years. Perhaps the most outstanding and important member of this family is the science or technology called "materials research." As Dr. Harold Weber of MIT and Army has put it, actually we have always had the question of materials with us, but modern technological advances have accentuated the problems. The cast iron and alloy steels that were plenty good enough for steam engine construction are useless in the high temperatures of today's gas turbines and jets. Today's rubber will be quickly replaced by the newer and more durable plastic-type rubbers just now emerging from the laboratories.

For the most part, materials as they occur in nature are unsatisfactory for the exacting demands of modern technology. This is true, be it in wood replaced by synthetic sheet material, natural fibers replaced by dacron or nylon, or oil-based paints replaced by plastic-based emulsion coating materials.

A frantic search is on for really satisfactory high-temperature lubricants. The imminent availability of liquid hydrogen in large commercial quantities is an example of a newly-available commer-

cial liquid material which may well open up new avenues in power generation, air travel, and chemcial synthesis.

Foods can be included in the area of materials research. A firm in Boston has developed a line of "synthetic meats" based on reconstituted tuna fish. These foods are delicious, and for uniformity and quality surpass their natural counterparts. From these it is but a step to new food products unlike any produced by nature, and in endless variety.

Optical glass is another material that continues to offer challenges to the physical scientists. We need special glasses for multifocal lenses, tinted glasses for special glare conditions, and glasses whose physical properties other than that of refraction will enable them to be used where the traditional types of glass fall down in practice. Refractive substances other than glasses are being sought. The availability of new rare earth oxides opens up the opportunity of modifying the present optical glasses.

Ceramics for structural use, particularly at high temperatures, are another goal to shoot for. Unfortunately, those ceramics which are heat resistant and have useful high-temperature strength, ductility, and toughness have long been found to be brittle and not suitable for engineering use. The problem of finding ductile, tough, ceramics is not now as hopless as it was once thought to be, and research endeavor in this area has much promise of payoff. The search for a rational procedure for design against fracture is a leading challenge today in the field of metallurgy.

The possibilities in the field of electronics are legion. The engineers and physicists are seeking ways, for example, to achieve TV picture screens that require a relatively negligible front-to-back distance; cheaper and better color TV; inexpensive remote controls for TV; an automatic collision-preventing device for autos; automatic steering of autos; better computers; image intensification for better night viewing; panel lighting for homes.

In the field of electrical and power engineering, the greatest challenge today is further increase in the efficiency of power-generating devices, those that use present-day fossil fuels. Much progress has been made in this field, perhaps the greatest single forward step in the past decade having been the trick of "inner cooling" of the electrical conductors of generators, using hydrogen gas as the coolant. This has enabled a doubling of the electrical output of a given machine, and single-unit generators of the order of 350,000 kw are now possible.

In the field of physics, the leading challenges of today include: finding a comprehensive theory for elementary nuclear particles and nuclear structure; improved knowledge of gas adsorption and desorption on surfaces; an understanding of the basis of gravitation; better materials or processes for shielding against radiation; improved instrumentation for radiometry; methods for plasma diagnosis; better understanding of surface friction; more knowledge of cosmic and interplanetary radiation; more knowledge of the structure and properties of metals, alloys, semiconductors, luminous materials, and other solids; direct conversion of nuclear fission energy into electrical power; and the use of atomic or nuclear resonances for missile guidance.

A recent discovery that came out of pure basic research in physics is called optical pumping. This is the process of increasing the internal energy of individual atoms by means of radiation such as in the form of visible light. The ability to do this opens up exciting possibilities to the basic physicist for learning more about the structure of atoms, and offers to the applied physicist a number of practical applications as well. One of these may be the generation of visible or infrared radiation in coherent form, which would be a revolutionary achievement. This process has been dubbed "light amplification by stimulated emission of radiation," which shortens down to a new word, LASER.

In chemistry and chemical engineering some of today's challenges are: successful fuel cells, to convert fuels directly into electrical energy; conversion of sea water to fresh water for general home and industrial use at reasonable cost; a better understanding of corrosive processes and ways to prevent them; the making of new materials, through high temperature and high pressure processes, having unusual or superior physical properties; particularly with respect to resistance to corrosion, erosion, and heat; the discovery of new fuels having high specific energy or impulse; development of inorganic surface coatings that have high bonding strength; the discovery or development of new methods of chemical analysis.

The polymer chemist is engaged in synthesis of new polymers to serve as films, plastics and elastomers, and coating and adhesives. The immediate goal of this research is to make still-harder polymers, so as to enrich the spectrum of useful structural materials. However it may help lay the groundwork for an eventual study of the origin of life.

Some nonmilitary objectives in the field of rocketry and jet propulsion include: flight at 3,000 mph; satellites serving as naviga-

tional, meteorological, and communications agents; rocket mail and freight service; and space travel by man.

One general challenge of great importance is to maximize the flow of awareness of new findings, within and between all the sciences, and to insure the retrieval, when needed, of information that was written down one, five, or fifty years ago. My observations of the past 15 years lead to the opinion that the processes of flow, storage, and retrieval of information must be centered about human beings. No machine can give back more intelligence than that put into it by a human being. I take a very reserved view of the many attempts made in the past twenty years to mechanize the storage, flow, and retrieval of information by automatic machine processes. The challenge we face here can be answered, it seems to me, only by making up our minds that a certain fraction of our educated people must be paid well enough to make them be willing to serve others, working as "information passers." This requires that they forego the personal glory and excitement of being "discoverers." We must quit waiting for or expecting machines to do the job of analysis for us, for only people can do it. The Russians apparently have adopted just this policy. The Russian scientists seem to know more about what we are doing than our own scientists do, and they learn about it sooner. This is achieved simply by putting thousands of well-educated people to work, analyzing the free-world scientific literature and locating the people within the Soviet borders that might make some use of it. At our office, for lack of men with specific training, we are using several intelligent young ladies who have Master's degrees in non-scientific subjects to aid our scientific staff in information analysis, and we find that they are well worth the dollars we pay them. Even so, we are not accomplishing the job as well as we would like to. However, our use of these young women shows that a good general education, high IQ, and the ability to sense the meaning of new words from a basic understanding of English and the root languages that underlie English has real value.

A group of famous physical scientists having international stature recently made a study to determine and list all the ways whereby the effectiveness of Western science might be increased. Many interesting comments are given in their report. Among them I found this one:

"In some nations, an attempt is made to compensate for the lack of science teachers by introducing general courses instead of

the traditional courses in various branches. Such general courses have a disastrous effect if they fail to instill the basic discipline of rigorous scientific thinking. If contraction (in the number of courses offered) is necessary, it is often far wiser to retain quality and to limit the number of subjects taught in a secondary school. In making such a choice, mathematics should be given the highest priority since it is fundamental to all the quantitative sciences, as well as to the development of logical thinking."

Their final conclusions constitute a long series of challenges, addressed to the NATO nations. I have selected several of these as the most significant for today's session, as follows:

A. All countries should introduce measures to increase the numbers of their scientists. These measures should include general educational programs whose object would be to kindle an enthusiasm for science in secondary schools . . .

B. An education in science should not necessarily be limited to those destined to become professional scientists, since training in science provides a valuable educational discipline and a basis for understanding much of our modern culture and some of the major forces which transform society today.

C. The exchange of scientists between industries and universities should be encouraged.

D. The teaching of science in secondary schools should be improved. All countries should introduce measures to increase the number of highly qualified teachers. Combining part-time teaching in secondary schools with work in universities should also be considered.

E. Measures should be devised to encourage women to enter professional scientific occupations in greater numbers.

F. Attention should be given to the establishment of new Technicians' Training Institutions, co-operative training arrangements permitting combined work and study, and the extension of correspondence training. The training of technicians for science and technology requires greater national attention.

The general public of the future must not only be able to read and write well and be mentally alert, but also must be able to measure, tabulate, calculate, and analyze; must possess a fair knowledge of fundamental physical and natural phenomena; and in general must be acquainted with the basic "tools and techniques" of the scientists and engineer. And as for the scientist, purely qualitative knowledge and cut-and-try methods are not enough; his work must be quantitative and reducible to theory, to measure up to the requirements of the future.

The Design and Analysis of Laboratory Experiences in High School Chemistry*

PAUL B. HOUNSHELL
Coordinator of Science and Mathematics
Winston-Salem City Schools

LABORATORY research is the essence of science, for through research the scientist explores the known in an attempt to understand the unknown and derive truth. Because of this inherent nature of science, laboratory work is as essential to science teaching as it is to science. Real experimentation not only develops the student's understanding of concepts and generalizations of science but, equally important, it allows the student to become involved in the ways of science and the scientist.

To uncover truths previously unknown to science cannot be an objective of laboratory experimentation and activity in the classroom; however, to uncover truths previously unknown to the student and to relate this new knowledge to that which he already knows is essential. Yet few high school science courses even approach meaningful laboratory experimentation for students. Science education authorities have for many years pointed out this deficiency, but for varied reasons it is still not being remedied Enrollment increases have undoubtedly placed most school units in financial crises; thus the establishment of ideal conditions in science departments has been hindered. Many educators feel, however, that a lack of understanding of how to organize and operate a successful laboratory course is the greatest weakness. Unfortunately most publications for use by teachers and students require little more than laboratory verification and 'filling in the blanks'. This will not fulfill the objectives of good science teaching.

As a means of adding to the understanding of how to organize and operate a successful laboratory in high school chemistry, this study was undertaken in the latter part of 1958 and continued through the spring of 1960. The purposes of the study were (1) to identify concepts basic to the study of high school chemistry, and (2) to design laboratory experiences for high school chemistry which develop functional and intellectual concepts basic to the study of chemistry, which utilize the problem solving approach, and which would be adaptable to various high school programs.

* Based on research done at the University of North Carolina in completion of requirements for the Doctor of Administrative degree.

The development of understanding of concepts is an undisputed objective of high school chemistry, yet the literature revealed an indeterminate number of interpretations of the meaning of a scientific concept. In this study, a concept is considered an organized unity of thoughts and ideas composed of similar and interrelated elements continually developing from facts and principles.

Since the development of understanding of chemical concepts is a major objective of high school chemistry, all activities must be directed toward the formation of this understanding. Laboratory work, then, must be an integral phase of the total chemistry program and it must be interwoven into the framework of the course so that it will contribute to the understanding of concepts as well as contribute to other significant objectives. Concepts appropriate only for laboratory activity, with additional concepts for all other work would be totally unrealistic. For this reason, the concepts basic to the total high school program were identified.

To identify the basic chemical concepts, forty-five (45) science textbooks for grades one through twelve, college textbooks and laboratory manuals, and current literature were analyzed. Thus, subject matter of chemistry as well as the chemistry professors, these three basic concepts appropriate for high school chemistry were identified:

1. All matter is composed of atoms which exhibit characteristics enabling them to be classified and grouped according to their individual characteristics.
2. The structure and internal energy of atoms cause them to combine to form molecules of various compounds each with its particular characteristics.
3. By controlling external conditions of reactions, products from changes of atoms, molecules, and compounds and the energy involved can be utilized.

While the development of an understanding of chemical concepts is a primary objective of high school chemistry laboratory courses, there are other factors which must be considered for laboratory activities to achieve maximum effectiveness. For example, if students are to become involved in the ways of science and the scientist, they must be encouraged to participate actively in the solution of problems. They must be given an opportunity to use and appreciate a scientific method; they must be given a chance to think. To help fuse these many factors into an effective program, the following criteria were selected as guides for the design and organization of a series of laboratory experiences. (1) Contribution

of the experiences to the understanding of chemical concepts; (2) Opportunities provided for the solution of problems; (3) The adaptability of the problems to various experience levels, such as subject matter maturity, group and individual interests, and abilities of students; (4) Equipment necessary to carry out the experience; and (5) Time required to carry out the experience.

Using these five criteria, twenty-three (23) representative experiences were designed for high school chemistry. Through its organization, each experience is directed toward the inductive solution of a problem, and exploration of the problem will contribute to the understanding of one or more chemical concepts. Several activities are included in each experience, yet all are directed toward the solution of the same problem. Many of the activities require experimentation, others are merely manipulative, while recording and analysis of data, observation, and reading are stressed in each of the experiences. Thus through these learning activities, the student is required to work with the facts of chemistry. The understanding derived from these activities and from the solution of the problems contributes to the understanding of concepts.

The twenty-three experiences are not the only ones suitable for establishing the three concepts listed above nor do they represent a complete laboratory course for high school chemistry. They are sample experiences, representative of a type designed to allow an inductive approach to the study of chemistry in the laboratory. Each experience was designed around a problem directly related to a basic chemical concept. An "introduction to the problem" was presented to the student. It was the purpose of "the introduction" to acquaint the student with the various factors involved in the problem and to motivate the student to recall facts and skills necessary for the solution of the problem. Apparatus and materials" needed were given. "Procedures" were presented with "Guides for Observation." Basic to the purpose of stimulating inductive thinking were the "Guides to Analysis and Conclusions." For each problem suggestions were given to the student as guides. It was the intent of the author to allow as much freedom as possible for the student to record observations, draw analyses, and form conclusions. Suggestions for "Further Study" were presented at the conclusion of each experience.

Each of the twenty-three experiences was analyzed by a panel of high school chemistry teachers and college professors of chemistry and science education in order to determine their apparent effectiveness in terms of the selected criteria. In addition, a class of high

school chemistry students performed the experiences under the guidance of the writer. On the basis of opinions of the participants in the study, the twenty-three experiences were considered effective in terms of the selected criteria.

The findings of this study indicated both that high school chemistry laboratory programs should be organized around problems which provide opportunities for students to become totally involved in their solution and that experiences should be designed to allow students maximum freedom of thought and activities. Students should be given ample time and adequate facilities to determine experimentally factors relating to the solution of problems, to obtain and record significant data, and to analyze this data as it relates to the problem. The total high school chemistry program, as well as chemistry in all lower grades, should be directed toward the formation of an expanding understanding of chemistry concepts.

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